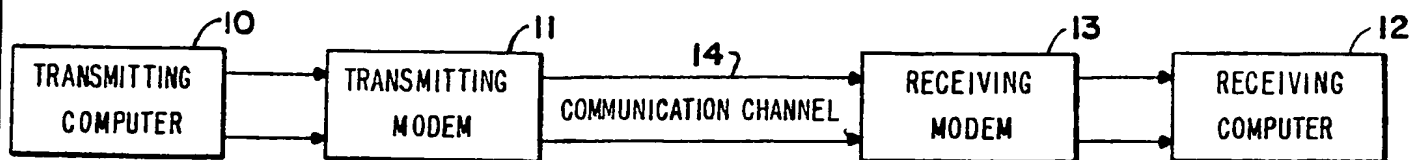


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(54) Title: METHOD AND APPARATUS FOR EFFECTING EFFICIENT TRANSMISSION OF DATA

**(57) Abstract**

A telecommunications system (11) intermittently checks and, if necessary, adjusts the power level of the transmitted data as a function of the transmission characteristics of the transmission line (14) so as to optimize transmission performance.

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METHOD AND APPARATUS FOR EFFECTING
EFFICIENT TRANSMISSION OF DATA

1 This invention relates generally to a
2 telecommunications system adapted to transmit digital data,
3 and more particularly to a system which intermittently
4 checks and, if necessary, adjusts the power level of the
5 transmitted data as a function of transmission
6 characteristics of the transmission line so as to optimize
7 transmission performance.

8

9

BACKGROUND OF THE INVENTION

10 While microcomputers were once only used as dedicated
11 and completely isolated devices, they are now used for a
12 wide range of applications, many of which require
13 microcomputers to communicate with each other or with
14 larger centrally located computers. This communication
15 frequently is accomplished over voice grade communication
16 channels. Modems are used to convert digital data from the
17 computer to analog data for transmission over these voice
18 grade communication channels and subsequent redigitization
19 upon receipt. As signal processing techniques have
20 advanced, modem technology has also advanced providing the
21 capability of transmitting at higher speeds over voice
22 grade channels. Problems maintaining the data integrity
23 across the communications channel have developed with such
24 high speed communication because the higher speed data
25 transmission methods are more vulnerable to noise
26 interference within the communication channel. To
27 facilitate higher speed communications, communications
28 protocols have been developed to detect and correct data
29 transmission errors and ensure data integrity across the
30 channel.

31 A communication protocol is basically a set of rules
32 that defines how communicating devices interact. For one
33 device to transfer data successfully to another, both
34 devices must observe the same protocol. Typically, a

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1 protocol specifies when to send a message, how to format
2 the information in the message, and at the other end, how
3 to acknowledge the receipt of the message.

4 Simple physical connect protocols are concerned only
5 with hardware configurations. Establishing the basic
6 physical connection between two modems requires that a
7 particular series of steps be followed. The originating
8 modem initiates its sending sequence, and the telephone
9 number representing the electronic address of the receiving
10 modem is formatted as a series of pulses or tones and sent
11 to the telephone network. The receiving modem senses the
12 incoming call as a relatively high voltage (sufficient to
13 cause a phone to ring) and interprets this as a request to
14 establish a connection. The modems then proceed to
15 establish the physical connection via a series of signal
16 exchanges that result in a particular connection protocol.
17 Such a connection is possible because both modems use the
18 same physical connect protocol. These basic physical
19 connect protocols are fairly standard. CCITT
20 specifications V.22, V.22bis, V.29, V.32 and V.32bis are
21 common as well as Bell 212A. These physical level
22 protocols do not ensure error free communication.

23 Connecting two computers is only a small part of the
24 communications work necessary for accurate data transfer.
25 As described in greater detail below, the transmission
26 medium through which the data is sent is often noisy, and
27 errors can crop up in the transmitted data. These errors
28 must be detected and corrected. The resources available to
29 store incoming data also must be passed and matched so that
30 the recipient is not flooded with data. These concerns,
31 therefore, go beyond the physical level protocols. A
32 higher level protocol is required to ensure error free
33 communications.

34 One protocol which enables error free communications
35 between modems is the Microcom Networking Protocol (MNP)
36 which has been developed by Microcom, Inc. of Norwood,
37 Massachusetts. MNP provides a sophisticated communications

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1 system which includes provisions for both reliable
2 terminal-type interactive communications and reliable file
3 transfer. MNP provides sophisticated error checking and
4 correction as well as data compression. MNP is widely used
5 to provide error free communications.

6 The MNP protocol, which has been developed principally
7 for use with microcomputers, includes three layers, and the
8 use of only three layers enable MNP to provide the
9 necessary services with the desired space and performance
10 characteristics for a microcomputer environment. The three
11 layers or modules are combined to perform a series of
12 complex functions in a manner in which changes in one
13 module may not drastically affect another module, as long
14 as certain parts of the module's interface remain the same.

15 In MNP, each layer is relatively isolated and provides
16 a specific service. If a change is forced in one layer
17 (for example, if MNP is modified for use on a new
18 computer), the change is confined to that layer while the
19 layer's standard interface to the other layers remains
20 unchanged. In addition to ensuring machine portability,
21 MNP's structure allows services provided by one layer to
22 support those in the layer above. The accumulation of
23 services is then passed upward, from layer to layer to the
24 applications program. MNP defines three unique protocol
25 layers in addition to the physical connection; the link,
26 the session, and the file protocol layers. The protocol
27 layers are triggered sequentially from the bottom
28 (physical) to the top (file transfer).

29 The link layer is responsible for providing reliable,
30 controlled data transmission over a medium that is
31 inherently noisy and likely to cause errors. Once a
32 physical connection is established between two modems, the
33 link protocol acts as a negotiator causing both devices to
34 agree on the nature of the link. For example, the link
35 protocol establishes whether the connection will be half-
36 or full-duplex, how many data messages can be sent before
37 confirmation is required, the size of a single data packet,

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1 etc. As will be more evident hereinafter, the link
2 protocol utilized in the preferred embodiment is modified
3 to include the necessary information to carry out the
4 principles of the present invention. After establishing
5 values for the above requirements, the link protocol
6 initiates data transfer, paces the flow of data and, if
7 necessary, re-transmits data messages that contain errors
8 due to telephone line noise. The link protocol allows
9 blocks or packets of data (as opposed to individual bytes)
10 to be sent synchronously or asynchronously to the receiving
11 computer. Data transfer is faster when packets are
12 transmitted synchronously because start and stop characters
13 are not needed, and as a result, the ratio of data to
14 control characters regulating the transfer is higher.
15 Control is possible because of a mainframe-like (framing)
16 technique in which a block of data is carried from both
17 ends with specific codes.

18 In order for any communications protocol to facilitate
19 communications among a wide variety of computers, the
20 protocol must be able to operate in a number of modes.
21 These modes include a matched-protocol mode for use by two
22 communicating devices supporting the same protocol. Such
23 a matched-protocol mode may provide optimized data
24 transmission including a number of known optimizing
25 features such as detecting and correcting errors, data
26 compression, and optimizing transmission speed. The latter
27 is achieved in the link layer of the MNP protocol by
28 sensing the error rate. Should the error rate be too high
29 at the receiving end, the receiving end provides an
30 indication that the signal to noise ratio is too low for
31 the attempted modulation rate (i.e., baud rate) so the
32 transmitting modem downshifts, i.e., transmits at a slower
33 modulation rate to improve signal quality. Conversely,
34 should the transmission of data be error free the receiving
35 modem can instruct the transmitting modem to upshift to a
36 higher modulation or baud rate so that data can be
37 transmitted at a higher and more efficient modulation rate

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1 so as to increase data throughput without sacrificing
2 quality.

3 Certain communication channels, such as cellular
4 networks, are particularly noisy. The noise levels in the
5 transmission channels are directly related to the signal to
6 noise ratio, which in turn is directly related to the
7 available throughput (the maximum rate at which information
8 can pass through the particular transmission channel).
9 Even worse, as transmission of a signal passes from one
10 cell to another cell in a cellular communications network
11 the quality of the line can abruptly change. This wide
12 range of line quality can result in demodulation errors.
13 Worse, the line temporarily can disconnect resulting in
14 disruption in the line. While such disruption can be
15 acceptable for voice communications it can be disastrous
16 for data transmission since the carrier signal, and thus a
17 great deal of transmitted data, can be lost. In the latter
18 situation the two modems must be "retrained" so that the
19 two modems are suitably resynchronized with one another and
20 data can be transmitted between the two.

21 This problem is exacerbated because companding
22 techniques often are utilized in cellular communications
23 because the dynamic range of the transmission medium is
24 particularly small (the power level range between a floor
25 where noise will mask a transmitted signal, and a ceiling
26 where transmitted signals saturate and thus distort).
27 Accordingly, signals are first dynamically compressed prior
28 to being transmitted through the transmission channel, and
29 subsequently dynamically expanded when received from the
30 transmission medium so as to preserve the dynamic range of
31 the original signal. When compressing a signal the gain
32 impressed on the transmitted signal is automatically
33 controlled as a function of the power level of the original
34 signal so that the power level is actually boosted for low
35 power levels and attenuated for high power levels by a
36 predetermined compression factor (as a function of the
37 dynamic range of the transmission medium). Thus, a greater

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1 range of power levels of the transmitted signal, once
2 compressed, can be transmitted within the narrower dynamic
3 range of the transmission channel. The signal is expanded
4 in a complementary manner at the receiving modem so that
5 the signal is restored to its original dynamic range
6 without distortion or loss. This compression and
7 complementary expansion factor (i.e., companding factor) is
8 typically determined by the location of the floor and
9 ceiling of the dynamic range of the transmission medium,
10 and for cellular communications is specified in cellular
11 network standards. It is customary that the power level of
12 the original signal is preset at a predetermined level
13 above the noise floor of the transmission channel when
14 transmitting the signal so as to optimize the transmission
15 performance. This easily can be done for a communication
16 channel where the dynamic range and noise floor are fairly
17 fixed. However, in cellular communications as the
18 transmission of a signal is passed from one cell to
19 another, the transmission characteristics of the channel
20 may change (i.e., the attenuation drop can vary), which in
21 turn can result in the power level of the received signal
22 dropping below the noise floor. This can result in the
23 noise masking the signal causing data to be lost or
24 received in error. Thus, the optimum power level for
25 transmission through one cellular transmission channel may
26 not be optimum for another.

27 28 OBJECTS AND SUMMARY OF THE INVENTION

29 It is therefore a principal object of the present
30 invention to provide an improved system for and method of
31 transmitting data in which the power level of the
32 transmitted signal is adaptive to transmission
33 characteristics of the transmission line so as to optimize
34 transmission performance.

35 Another object of the present invention is to provide
36 a system for and method of data transmission in which the
37 optimum power level of the transmitted signal is

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1 intermittently determined in real time as a function of the
2 transmission characteristics of the transmission channel.

3 Still another object of the present invention is to
4 provide a data communications system and method in which
5 the optimum power level for transmitting signals between
6 two modems is updated when upshifting or downshifting the
7 modulation rate, or retraining to resynchronize the modems.

8 Yet another object of the present invention is to
9 provide an improved data communications system and method,
10 particularly useful for compressed signals transmitted over
11 a communications channel, in which the power level of the
12 transmitted signal is optimized as a function of the
13 intermittently measured quality of the transmission channel
14 through which the signal is transmitted.

15 These and other objects of the present invention are
16 provided by an improved data communications system and
17 method which intermittently updates, and changes if
18 necessary, the power level of a transmitted signal as a
19 function of the location of the noise floor of the
20 transmission channel and line attenuation so as to
21 approximate the power level for optimum transmission
22 performance through the channel and accommodate changes in
23 transmission characteristics in the channel.

24 Other objects of the invention will in part be evident
25 and will in part appear hereinafter. The invention
26 accordingly comprises the processes involving the several
27 steps and the relation and order of one or more of such
28 steps with respect to each of the others, and the apparatus
29 possessing the construction, combination of elements, and
30 arrangement of parts which are exemplified in the following
31 detailed disclosure, and the scope of the application of
32 which will be indicated in the claims.

33

34

BRIEF DESCRIPTION OF THE DRAWINGS

35 For a fuller understanding of the nature and objects
36 of the present invention, reference should be had to the
37 following detailed description taken in connection with the

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1 accompanying drawings wherein:

2 Fig. 1 is a generalized schematic view of a data
3 telecommunications system of the type including two modems
4 incorporating the present invention;

5 Fig. 2 is a schematic view of a modem of the present
6 invention;

7 Fig. 3 is a graphical illustration showing an example
8 of a typical relationship of eye quality monitor data and
9 the signal to noise ratio of the transmission channel for
10 quadrature amplitude modulated (QAM) signals;

11 Fig. 4 is a graph illustrating the limits of power
12 level of a transmitted signal through a transmission
13 channel of a typical cellular network;

14 Fig. 5 is a flow diagram of the steps utilized by the
15 modem of the present invention in optimizing the
16 transmitted power level as a function of transmission
17 characteristics of the transmission line;

18 Fig. 6 is a flow diagram of a subset of steps utilized
19 by the modem of the present invention relating to the check
20 line quality step 104 of the flow diagram of Fig. 5; and

21 Fig. 7 is a flow diagram of a further subset of steps
22 utilized by the modem of the present invention relating to
23 the update transmit level step 206 and 215 of the flow
24 diagram of Fig. 6.

25

26 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

27 A basic data telecommunications system incorporating
28 the present invention is shown in Fig. 1 and includes a
29 transmitting unit of data terminal equipment (DTE) 10, such
30 as, but not limited to, a dumb terminal or a microcomputer,
31 and a receiving unit of DTE 12. An initiating modulator/
32 demodulator (modem) 11 is connected between unit 10 and a
33 communication channel (such as, but not limited to a
34 cellular network transmission channel) and a receiving
35 modem 13 is connected between unit 12 and communication
36 channel 14. It should be appreciated that while
37 designating one computer and modem as initiating and the

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1 other computer and modem as receiving, in reality in most
2 instances both are capable of transmitting and receiving
3 data between one another through the transmission channel.
4 Thus, the designations are for convenience, with the
5 designations "initiating" and "transmitting" used to mean
6 that a computer and modem are transmitting data, and the
7 designation "receiving" used to indicate that a computer
8 and modem are receiving data from the transmitting modem.

9 A modem of the communication system of the present
10 invention is shown in greater detail in Fig. 2. The
11 communications system of the present invention will
12 normally include at least two modems of the type described
13 below. For purposes of the following discussion, the modem
14 of the system will be described with reference to both the
15 transmitting and receiving modes, and thus will apply to
16 each of the modems 11 and 13 of Fig. 1. The modem shown in
17 Fig. 2 includes a DTE-interface 15 which receives data
18 coming from corresponding DTE unit. Data characters
19 supplied to the DTE-interface 15 pass through a
20 communications port 16 of the microprocessor 18 to which
21 characters are fed either in a serial or parallel fashion.
22 The microprocessor 18 has connected to it status indicators
23 20, a program and data memory 22 (the latter including a
24 buffer memory 23) and parameter setting switches 24.
25 Timing synthesizing circuitry 26 is also connected to the
26 microprocessor 18. Data processed by the microprocessor 18
27 is sent through a modem port 28 to modulation circuits 30
28 which in turn will pass data through a filter 32 before
29 applying the signals to the interface 34. In the case of
30 cellular network transmission, the signal is applied to a
31 transceiver 36, equipped with a compander for compressing
32 the transmitted signal before transmitting the signal over
33 the communication channel 14 to the remote modem. The
34 modulation circuits 30 preferably are adapted to modulate
35 the signal to be transmitted in accordance with a
36 quadrature amplitude modulation (QAM) technique at any one
37 of several modulation or baud rates, which can change with

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1 an upshifting, downshifting or retraining operation, which
2 will be described in greater detail hereinafter in
3 connection with a description of the preferred embodiment
4 of the present invention.

5 The modem of Fig. 2 also includes demodulation and
6 data recovery circuits 38 used for receiving and
7 demodulating data from another remotely situated modem.
8 When the modem of Fig. 2 acts as a receiving modem, data
9 passes through transceiver 36 (where the transmitted
10 compressed signal is expanded to its original dynamic
11 range), interface 34 and filter 32 to the circuits 38. The
12 demodulation rate is set based on the modulation rate.
13 Accordingly, provision is made as a part of the link
14 protocol for determining the modulated rate at which data
15 is to be transmitted and setting the demodulation and data
16 recovery circuits 38 accordingly.

17 According to the present invention, the modems of the
18 system function to intermittently update, and change if
19 necessary, the power level of a transmitted signal as a
20 function of the line quality (i.e., in the preferred
21 embodiment the location of the noise floor of the
22 transmission channel) and an indication of the received
23 level of the transmitted signal (i.e., in the preferred
24 embodiment the received level is an indication of line
25 attenuation) so as to approximate the power level for
26 optimum transmission performance through the channel and
27 accommodate changes in transmission characteristics of the
28 channel.

29 More specifically, as indicated in Fig. 3, as is well
30 known there is a relationship between what is referred to
31 as the eye quality monitor (EQM) value and the signal to
32 noise (S/N) ratio (and thus the position of the noise
33 floor) of the transmission channel 14. Thus, the EQM value
34 is one measure (when transmitting a QAM signal) of line
35 quality. The EQM value is determined as the filtered
36 squared magnitude of the error vector, the latter being
37 defined as the angle and magnitude difference between an

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1 actual received signal point of a QAM signal, and its ideal
2 location in the baseband signal plane. As is well known in
3 the art the EQM value may be obtained by processing the
4 error vector data to obtain a positive hexadecimal value
5 whose magnitude is an indicator of the quality of the
6 received signal or probability of error of received signal
7 points. See Laiz, Carlos; "Quality of Received Data for
8 Signal Processor-based Modems"; Rockwell International;
9 Document No. 29220N71; Application Note Order No. 671;
10 February, 1985; pages 1-20. In accordance with the the
11 present invention, an EQM value is preselected as a
12 function of the minimum permissible S/N so that the power
13 level of the transmitted signal is as close to the noise
14 floor as permitted without significant loss of information.
15 The ideal power level is initially presumed to be -10dB,
16 although this will vary in accordance with the principles
17 of the present invention based upon the attenuation over
18 the transmission channel. Accordingly, the modem of the
19 present invention includes means 40, connected with the
20 demodulation circuits 38, for providing a signal
21 (preferably as a function of the EQM value determined from
22 a signal received over the channel 14) to the
23 microprocessor 18, representative of the line quality,
24 i.e., preferably the current S/N as sensed, in real time,
25 from the signals received from the remote modem, and thus
26 the location of the noise floor of the channel 14.

27 While the EQM value provides a good indication of how
28 far the received signal is from the noise floor in the
29 communication channel, for a given level of transmitted
30 signal, the level of the received signal (i.e., the line
31 attenuation) can vary and thus, there is no indication of
32 what the power level of signal should be when transmitting
33 the signal over the channel 14 so as to provide a desired
34 level of received signal. More specifically, as
35 illustrated in Fig. 4, the power level of the transmitted
36 signal drops as a function of the attenuation along the
37 transmission channel. Ideally, the EQM value of the

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1 received signal should be representative of a S/N as small
2 as possible without the noise masking the signal so as to
3 utilize as much of the dynamic range of the transmission
4 channel as possible. Thus, if a particular line
5 attenuation is assumed and the power level is set based
6 upon a particular EQM value which place the received signal
7 as close as possible to the noise floor at the receiving
8 end, a line providing greater attenuation may result in the
9 signal falling below the noise floor, while a line
10 providing less attenuation may result in signal saturation.
11 Accordingly, means 42, connected with the means 40, are
12 provided for intermittently measuring, in real time, the
13 attenuation along the channel 14 so that the power level
14 can be set so that the EQM value at the received end of the
15 channel 14 is at the appropriate preselected value. Means
16 42 therefore provides a signal representative of the line
17 attenuation of the channel 14, referred to in the preferred
18 embodiment as the "AGC value". Preferably, the line
19 attenuation is intermittently checked by transmitting a
20 signal as a known power level and measuring the power level
21 of the received signal.

22 According to the present invention, the preferred
23 modem of Fig. 2 intermittently checks and, if necessary,
24 changes the power level of the transmitted signal from one
25 modem to another by determining the EQM value provided by the
26 EQM means 40 and the AGC value provided by means 42. Each
27 time the EQM and AGC values are determined at the remote
28 modem, the values are transmitted back as a part of the
29 link protocol. Having the two measurements provides an
30 accurate measure of line transmission characteristics so
31 that the transmit power level can be set as low as possible
32 without the transmitted signal falling below the noise
33 floor.

34 The optimization is preferably performed
35 intermittently and in real time so that changes in the
36 transmitting environment will result in changes in
37 transmitted power level thereby maintaining optimum

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1 throughput.

2 In accordance with the present invention the
3 optimization of the transmitted power level is performed
4 during upshifts or downshifts of the modulation rate of the
5 transmitted signal, or during retraining when two modems
6 are reconnected. Referring to Figs. 5-7, the flow diagrams
7 show the operation of the modem in carrying out the
8 principles of the present invention, and preferably use the
9 MNP protocol to transmit local data and receive remote
10 data. The preferred program code for carrying out the
11 steps of the optimization of the power level is carried out
12 in the microprocessor 18, and is described and shown in
13 Appendix A.

14 Specifically referring to Fig. 5, the steps described,
15 with the exception of steps 104, 107 and 112, are well
16 known as a part of the error control function of the MNP
17 protocol and are described as a part of the preferred
18 embodiment within which the principles of the present
19 invention are utilized. As shown in Fig. 5, the error
20 correction function of microprocessor 18 polls the hardware
21 to obtain the values of EQM and AGC from means 40 and 42
22 necessary to carry out error correction and adjust the
23 power level in accordance with the present invention. In
24 this regard the system generates the link management idle
25 packet in order to establish a connection between the two
26 modems. Specifically, at step 101 of Fig. 5, the protocol
27 link is established, i.e., the originating modem sends a
28 link request to the remote modem. The receiving modem
29 receives and evaluates the link request to determine what
30 it can support and sends back similar information. In this
31 regard the information exchanged between the two modems
32 include the current values of EQM and AGC, which as will be
33 more evident hereinafter determines the initial power level
34 at which the signal is to be transmitted as indicated at
35 step 102. Initially, these values are set for a power
36 level of -10dB. After an initial settling time the values
37 of EQM and AGC are read. In the preferred embodiment in

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1 accordance with the MNP protocol, if not already set at the
2 highest modulation rate, it is preferred that the latter
3 initially is chosen as the initial transmission rate at
4 step 103.

5 Step 104 is the step at which the line quality is
6 checked, and is described in the form of a series of
7 substeps shown in flow diagram form in Fig. 6. Referring
8 to Fig. 6, step 104 includes steps 201-222, all of which
9 are intended to be a part of the MNP protocol, with steps
10 202, 206 and 215 being inserted within the protocol
11 according to the principles of the present invention. More
12 particularly, the subset of steps are designed to check the
13 line quality. If the link management idle frame is
14 received at step 201, the next transmit level is calculated
15 at step 202 and in particular in accordance with the subset
16 of steps shown in Fig. 7.

17 Referring to Fig. 7, calculations are made to
18 determine the next transmit level so that the values can be
19 updated at steps 206 and 215, described hereinafter.
20 Specifically, at step 301 the values of EQM and AGC are
21 validated. If the transmitting modem is unable to
22 determine values provided by the remote modem, the
23 transmitting modem transmits an indication of such
24 (preferably an FFHex byte) within the LMI frame as a part
25 of step 108 or 113 of Fig. 5, described hereinafter. The
26 subset of steps of Fig. 7 then returns to step 203 of Fig.
27 6. If however, updated values can be determined, they are
28 adjusted at steps 302 and 303 by the microprocessor. If,
29 for example, the initial transmit level is set at -22dB and
30 the level is received at -30dB, the line attenuation is -
31 8dB (the difference between the transmit and received
32 levels). The preferred transmit power level at which the
33 compander will provide unity gain is determined at step 302
34 based on the AGC value received from the other modem and
35 the current transmit power level. In addition, the minimum
36 transmit power level at which the noise floor will not
37 interfere with the data transmission is determined at step

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1 303 based on the AGC and EQM value received from the other
2 modem and current transmit power level. Given the two
3 measurements, the microprocessor utilizes an empirically
4 determined table, shown in Appendix A to adjust the signal
5 strength (power level) of the transmitted signal at step
6 302 based on one of the two measurements made at steps 302
7 and 303. The values in the table of Appendix A have been
8 empirically determined. As to which measurement is used to
9 set the next power level will depend of the EQM value. If
10 the EQM value indicates a high noise level at step 304, the
11 processor will utilize the data acquired at step 303 to set
12 the power transmit level from the table of Appendix A, as
13 indicated at step 306. If, however, the EQM value
14 indicates an acceptable noise level at step 304, the
15 microprocessor proceeds to step 305 and calculates the new
16 power level based on the AGC number from the table of
17 Appendix A. In either event the microprocessor returns to
18 step 203 shown in Fig. 6. Referring again to Fig. 6,
19 once the next transmit level has been determined, or if at
20 step 201 a link management idle frame has not been
21 received, the program proceeds to step 203 to see if the
22 "fall back" command has been received. If the fall back
23 command is received, indicating that the remote modem has
24 decided to downshift so that the current modem will receive
25 data at a slower rate, the microprocessor will provide an
26 acknowledgement at step 204. The modem will first update
27 the power level at which the modem will transmit at step
28 206 before proceeding to step 207 where the modulation rate
29 is actually changed to the next lower rate. At step 208
30 the system checks to insure the downshift is successful,
31 and if so the modem proceeds to step 105 of Fig. 5. If,
32 however, the modem is not successful at step 208, the modem
33 proceeds to step 205 to again try a fall back to a slower
34 modulation rate. If successful at step 205, the system
35 returns to step 206. However, if not, the modem proceeds
36 to disconnect.

37 If at step 203 of Fig. 6 the fall back command is not

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1 received, the microprocessor proceeds to step 209, the
2 quality of the line is measured at step 209 by sensing the
3 EQM value provided in the EQM means 40 so as to determine
4 whether the modem should downshift. If yes, the
5 microprocessor proceeds to step 210 to determine whether
6 the modem can operate at a slower speed. If yes, the modem
7 sends a fall back command at step 211 and proceeds through
8 steps 206, 207 and 208, (and step 205 if necessary) as
9 previously described. If, however, the modem cannot
10 downshift as determined at step 210 (the modem is operating
11 at its slowest speed), or if at step 209 the line quality
12 is not judged to be bad, the microprocessor proceeds to
13 step 212.

14 At step 212, the modem checks to see if a fall forward
15 command has been received from the remote modem, indicating
16 that the remote modem wishes to operate at a faster
17 modulation rate. At step 213 an inquiry is made as to
18 whether the modem can operate at a faster speed, and if not
19 the microprocessor proceeds to step 218 to send a fall
20 forward negative acknowledgement indicating to the remote
21 modem that the modem cannot operate at the faster speed.
22 The program then returns to step 105 of the flow chart of
23 Fig. 5. If, however, an upshift can occur the program
24 proceeds to step 214, whereupon a fall forward
25 acknowledgement signal is sent to the remote modem at 214,
26 the transmit level data is updated (in an identical way as
27 described above with respect to step 206, and substeps 301-
28 306). The modulation rate is upshifted at step 216, and
29 the system checks to be sure the upshift was successful at
30 step 217. If not the system repeats the steps 206, 207,
31 208 (and if necessary 205) by again updating the transmit
32 level and changing the modulation rate. If once again
33 unsuccessful the system disconnects. If successful at step
34 208 or step 217, the system returns to step 105 of Fig. 5.

35 If a fall forward command is not received from the
36 remote modem, the system proceeds to step 219. The line
37 quality is again checked by reading the EQM value. If the

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1 line quality is still good, a determination is made whether
2 to upshift at step 220. If yes, the system sends a fall
3 forward command to the remote modem and waits for the fall
4 forward acknowledgement signal to return at step 222. If
5 the latter signal is received the system proceeds through
6 steps 215, 216 and 217, and if unsuccessful at step 217,
7 proceeds through steps 206, 207 and 208 (and step 205, if
8 neccessary). If unsuccessful at step 205, the system
9 disconnects. If successful at step 217, or subsequently
10 successful at step 208 the system returns to step 105 of
11 Fig. 5. Similarly, if the line quality is judged at step
12 219 to be bad, or the modem cannot upshift at step 220, or
13 the fall forward acknowledgement signal is not received at
14 step 222, the system similarly returns to step 105.

15 Referring again to Fig. 5, at step 105, the
16 microprocessor determines whether a data packet is to be
17 sent. An idle timer is set at the end of the transmission
18 of each data packet and allowed to run until the next
19 packet is sent. Thus, the idle timer can be used to
20 determined whether the two connected modems are idle (no
21 data is being sent). The modems are considered idle if no
22 data is sent within a predetermined period of time, e.g.,
23 1.0 seconds. Thus, if no data packet is to be sent at step
24 105 the microprocessor proceeds to step 106 to determine
25 whether the idle timer has expired. If no, the
26 microprocessor proceeds back to step 104. If the idle
27 timer has expired, the microprocessor proceeds to step 107
28 where the current EQM and AGC values are read from the EQM
29 means 40 and AGC means 42. With the modems being
30 determined in the idle state, the link management idle
31 frame or packet is sent as indicated at step 108. The idle
32 timer is then reset at step 109 and the program returns to
33 step 104.

34 If at step 105 data is to be sent, the program
35 proceeds to step 110, wherein the receiving modem checks to
36 be sure no that no errors in the packet received from the
37 transmitting modem have occurred. If no, the next data

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1 packet can be sent as indicated at step 111, and the
2 program proceeds to reset the idle time at step 109 before
3 starting over at step 104. If an error is discovered at
4 step 110 the signal strength and quality are both read at
5 step 112 (in the same manner as step 107), and an link
6 management frame is sent at step 113 (in the same manner as
7 step 108), as described in greater detail in Fig. 7. From
8 step 113, the program proceeds to step 114 whereupon the
9 NAK'D (negative acknowledgement) data packet is
10 retransmitted, the idle timer 109 is reset at step 109 and
11 the program restarts at step 104.

12 The modem and its operation thus described provides an
13 improved system for and method of transmitting data in
14 which the power level of the transmitted signal is adaptive
15 to line conditions so as to optimize transmission
16 performance. The optimum power level of the transmitted
17 signal is intermittently determined in real time as a
18 function of the line conditions. The transmitted power
19 level is updated when checking whether to upshift or
20 downshift the modulation rate, or retraining to reconnect
21 modems. The system and method are particularly useful for
22 compressed signals transmitted over a transmission channel
23 in which the power level of the transmitted signal is
24 intermittently optimized as a function of the noise level
25 within and the attenuation across the communication
26 channel.

27 Since certain changes may be made in the above process
28 and apparatus without departing from the scope of the
29 invention herein involved, it is intended that all matter
30 contained in the above description or shown in the
31 accompanying drawing shall be interpreted in an
32 illustrative and not in a limiting sense.

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CLAIMS

What is claimed is:

1 1. A system for optimizing conditions for
2 transmitting and receiving data signals over a transmission
3 medium having transmission characteristics which may change
4 over time, said system comprising:
5 means for intermittently sensing the transmission
6 characteristics of said transmission medium; and
7 means for adjusting the power level of data signals
8 transmitted by said system over said transmission medium as
9 a function of said sensed transmission characteristics so
10 as to optimize transmission performance.

1 2. A system according to claim 1, wherein said means
2 for intermittently sensing the transmission characteristics
3 of said transmission medium includes means for generating
4 a signal as a function of the line quality, and means for
5 generating a signal as a function of the signal attenuation
6 along said medium.

1 3. A system according to claim 2, wherein said means
2 for generating a signal as a function of the line quality
3 generates said signal as a function of signal to noise
4 ratio of a received signal transmitted through said medium.

1 4. A system according to claim 3, wherein said signal
2 transmitted over said transmission medium is quadrature
3 amplitude modulated, and said means for generating a signal
4 as a function of the signal to noise ratio includes means
5 for determining the eye quality monitor value of said
6 received signal.

1 5. A system according to claim 2, wherein said means
2 for generating a signal as a function of the attenuation
3 along said transmission medium includes means for
4 generating a signal at an initial power level along said

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5 medium so that the attenuation can be measured along said
6 medium.

1 6. A system according to claim 2, wherein said means
2 for adjusting the power level of data signals transmitted
3 by said system over said transmission medium as a function
4 of said sensed transmission characteristics includes means
5 for storing a table of values empirically determined as the
6 appropriate values of transmitted power levels as a
7 function of the line quality and line attenuation.

1 7. A system according to claim 2, wherein said means
2 for generating a signal as a function of the attenuation
3 along said transmission medium includes means for
4 generating a signal at an initial power level along said
5 medium so that the attenuation and line quality can be
6 measured along said medium.

1 8. A method of optimizing conditions for transmitting
2 and receiving data signals over a transmission medium
3 having transmission characteristics which may change over
4 time, said method comprising the steps of:
5 intermittently sensing the transmission
6 characteristics of said transmission medium; and
7 adjusting the power level of data signals transmitted
8 over said transmission medium as a function of said sensed
9 transmission characteristics so as to optimize transmission
10 performance.

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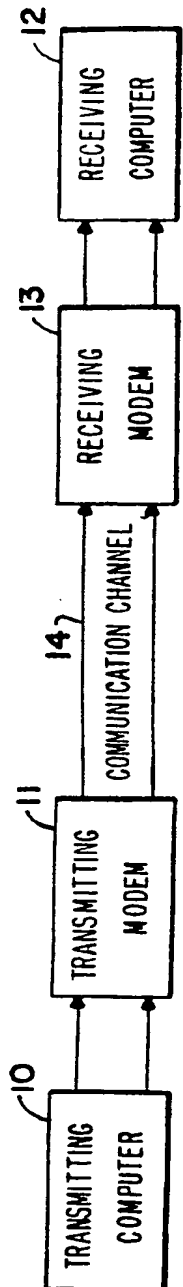


FIG. 1

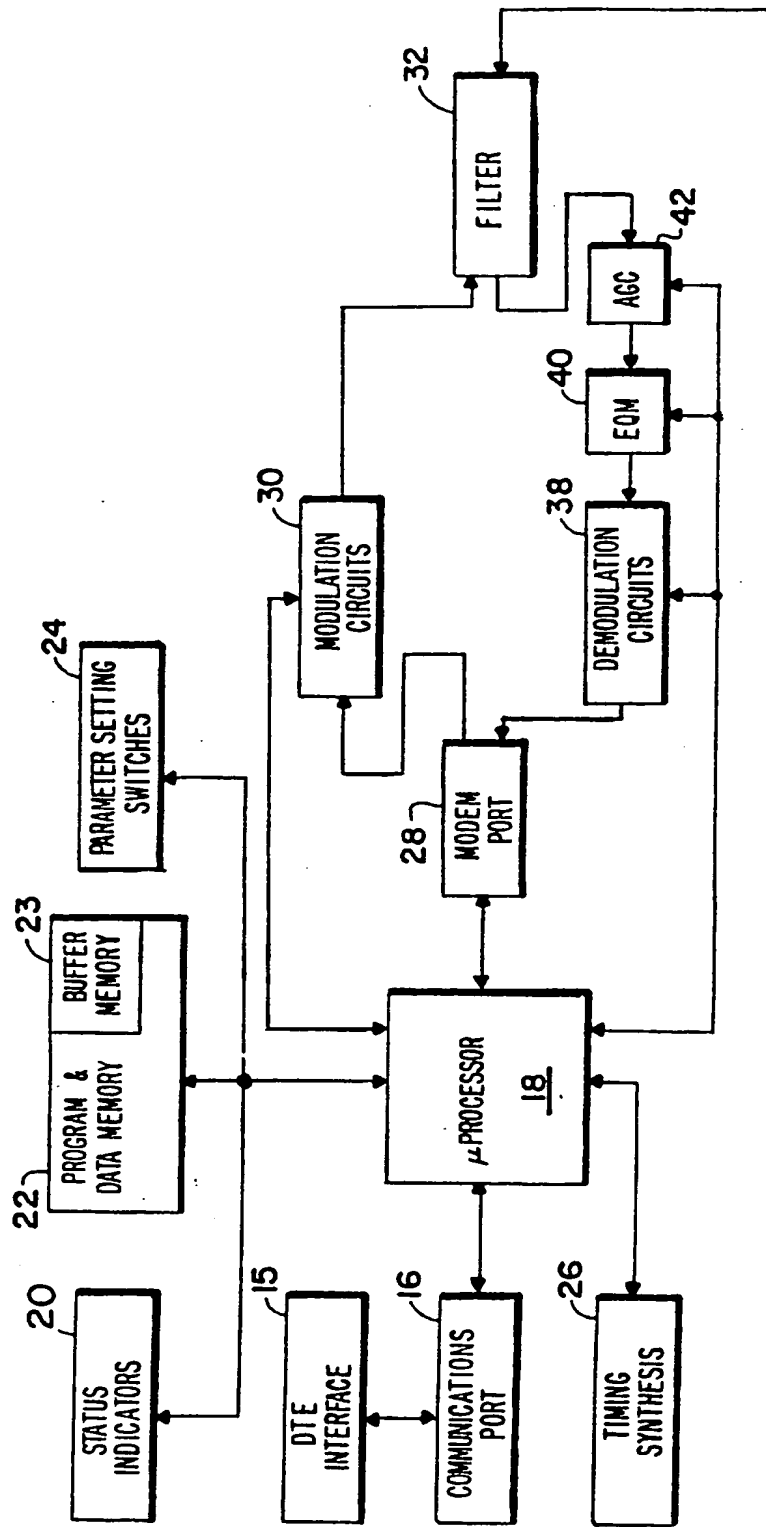


FIG. 2

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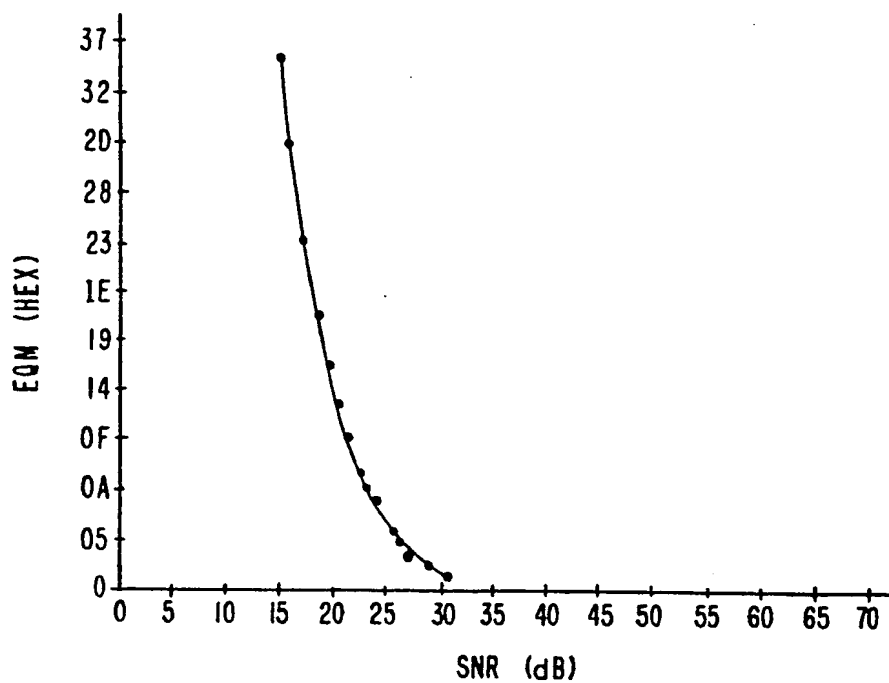


FIG. 3

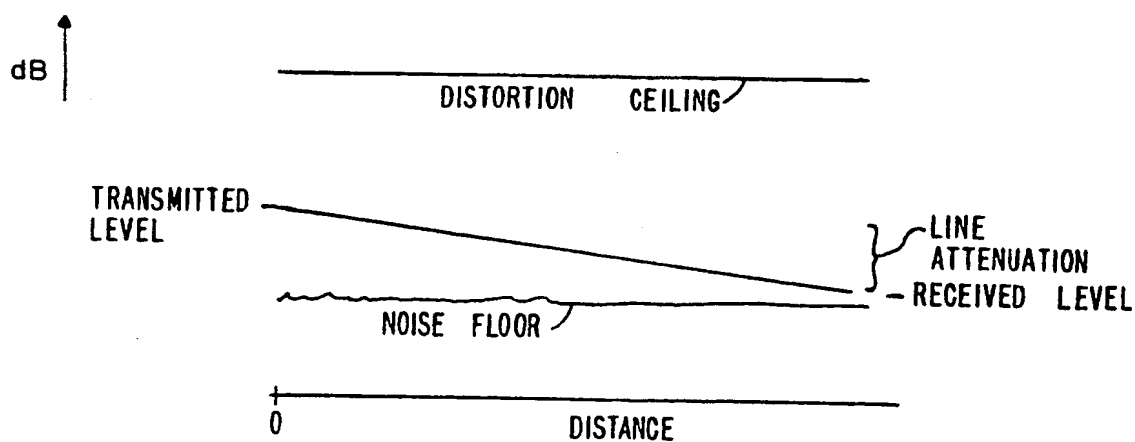


FIG. 4

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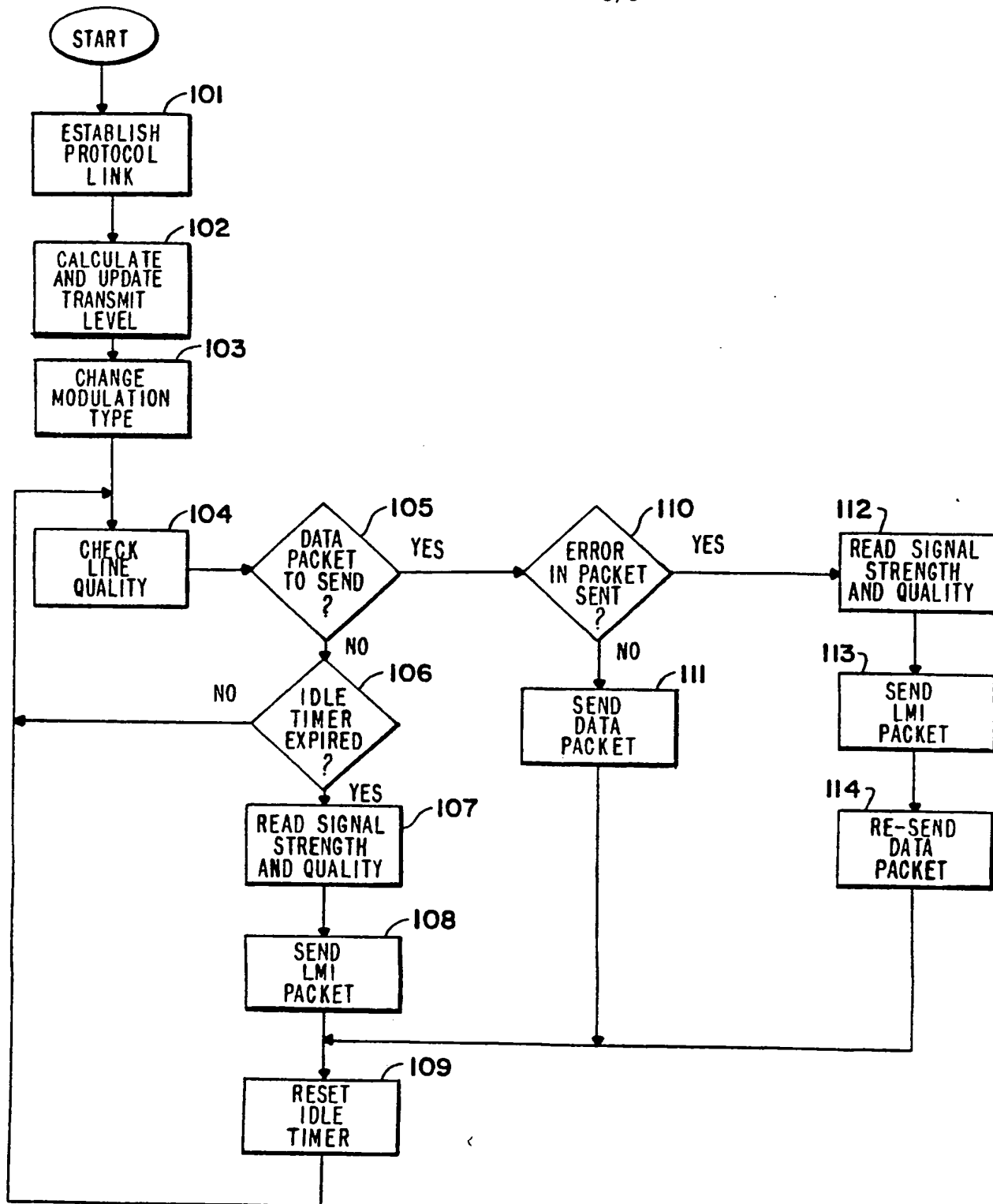


FIG. 5

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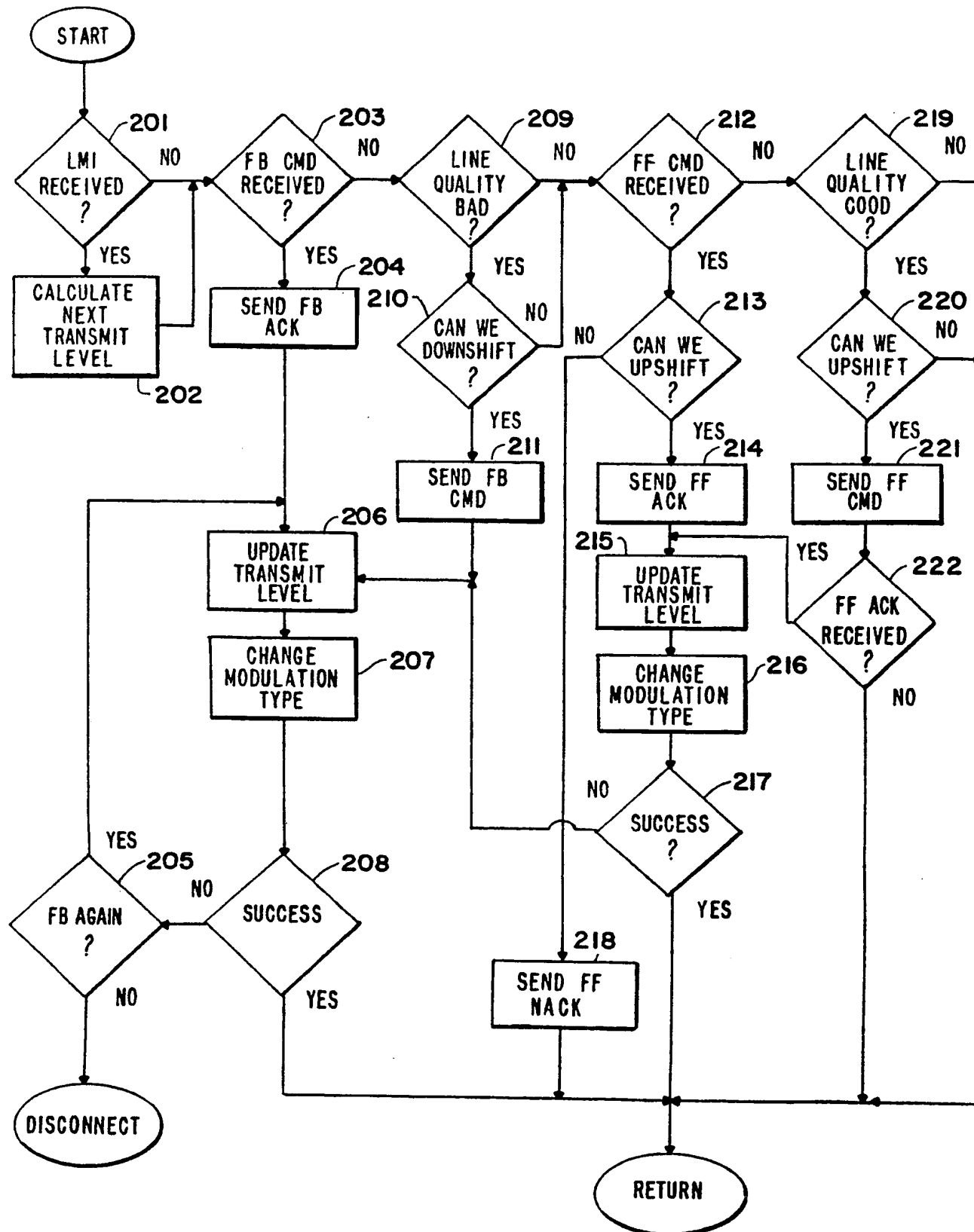


FIG. 6
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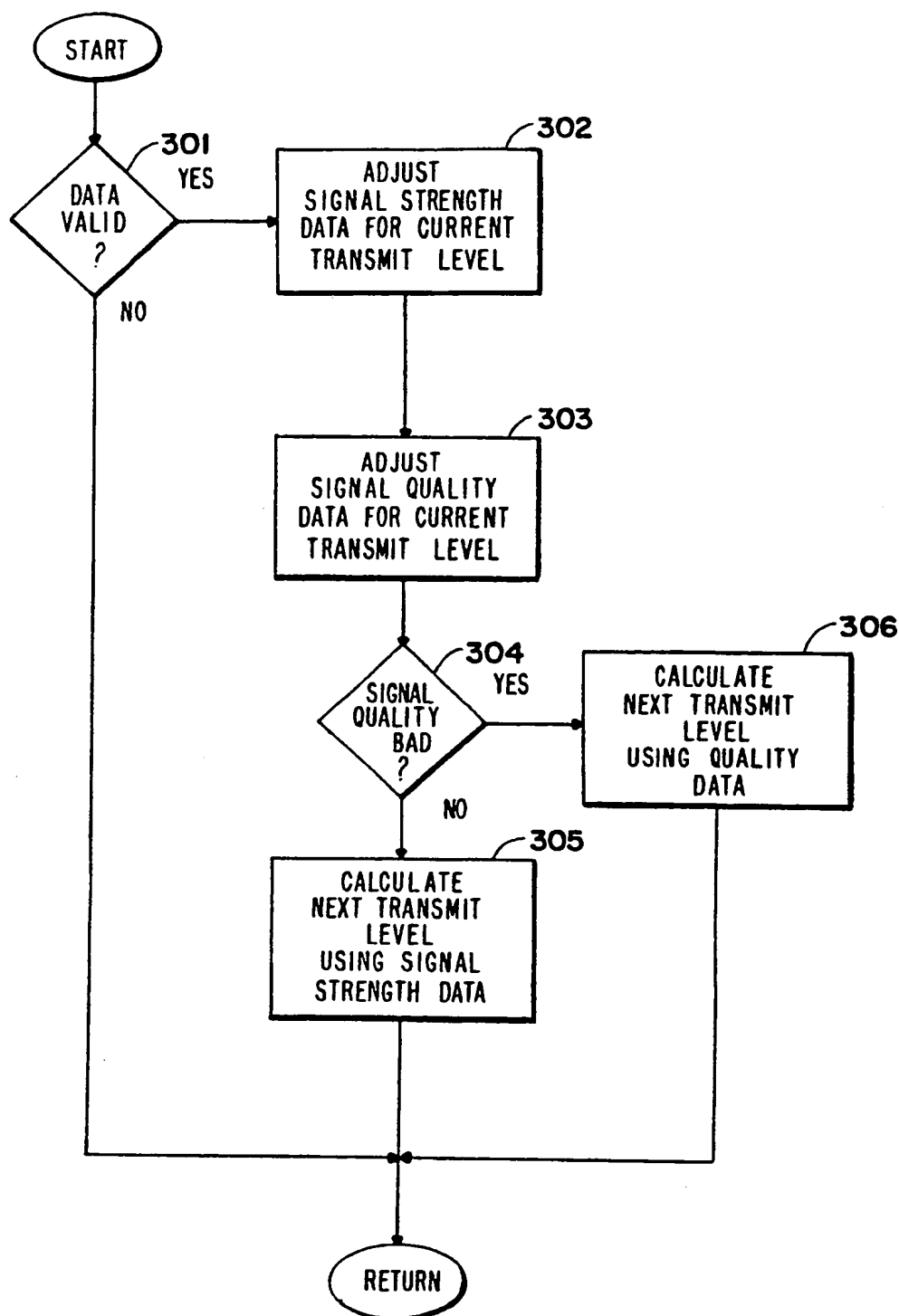


FIG. 7

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/05347

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :H04B 1/10, H04L 27/08

US CL :375/58

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 375/98.99; 455/10,52.1,69,70,72; 332/107

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,E	US, A, 5,128,965 (HENRIKSSON) 07 July 1992, Fig. 1.	1,8
Y	US, A, 4,910,792 (TAKAHATA ET AL.) 20 March 1990, Fig. 5 or Fig. 6.	1,8
Y	US, A, 4,309,771 (WILKENS) 05 January 1982, Fig. 2 and Fig. 4.	1,4,8
A	US, A, 4,004,224 (ARENS ET AL.) 18 January 1977.	1,8
A	LAIZ, CARLOS, "Quality of Received Data for Signal Processor-Based Modems"; Rockwell International; document No. 2922ON71; Application Note Order No. 671; 2/85; pgs. 1-20.	3, 4

☐

Further documents are listed in the continuation of Box C.

☐

See patent family annex.

* Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be part of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*&*	document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means		
P document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

13 AUGUST 1992

Date of mailing of the international search report

29 OCT 1992

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